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The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water

HYDROPOWER ASSESSMENT REPORT

SUPPORTING DOCUMENT 1:

INTERIM INVESTIGATION FOR HYDROPOWER POTENTIAL AT IMPENDLE DAM AND SMITHFIELD DAM TRANSFER SYSTEM

FINAL

MARCH 2014

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Compiled by:	***P Ramsden, D vd Merwe*** ***D B Badenhorst***
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CONSULTANTS: AECOM (BKS*) in association with AGES, MM&A and Urban-Econ.

Approved for ***Consultants****:*

P Ramsden	***D B Badenhorst***
Sub-Task Leader	*Task Leader*

DEPARTMENT OF WATER AFFAIRS (DWA): Directorate: Options Analysis

Approved for ***DWA****:*

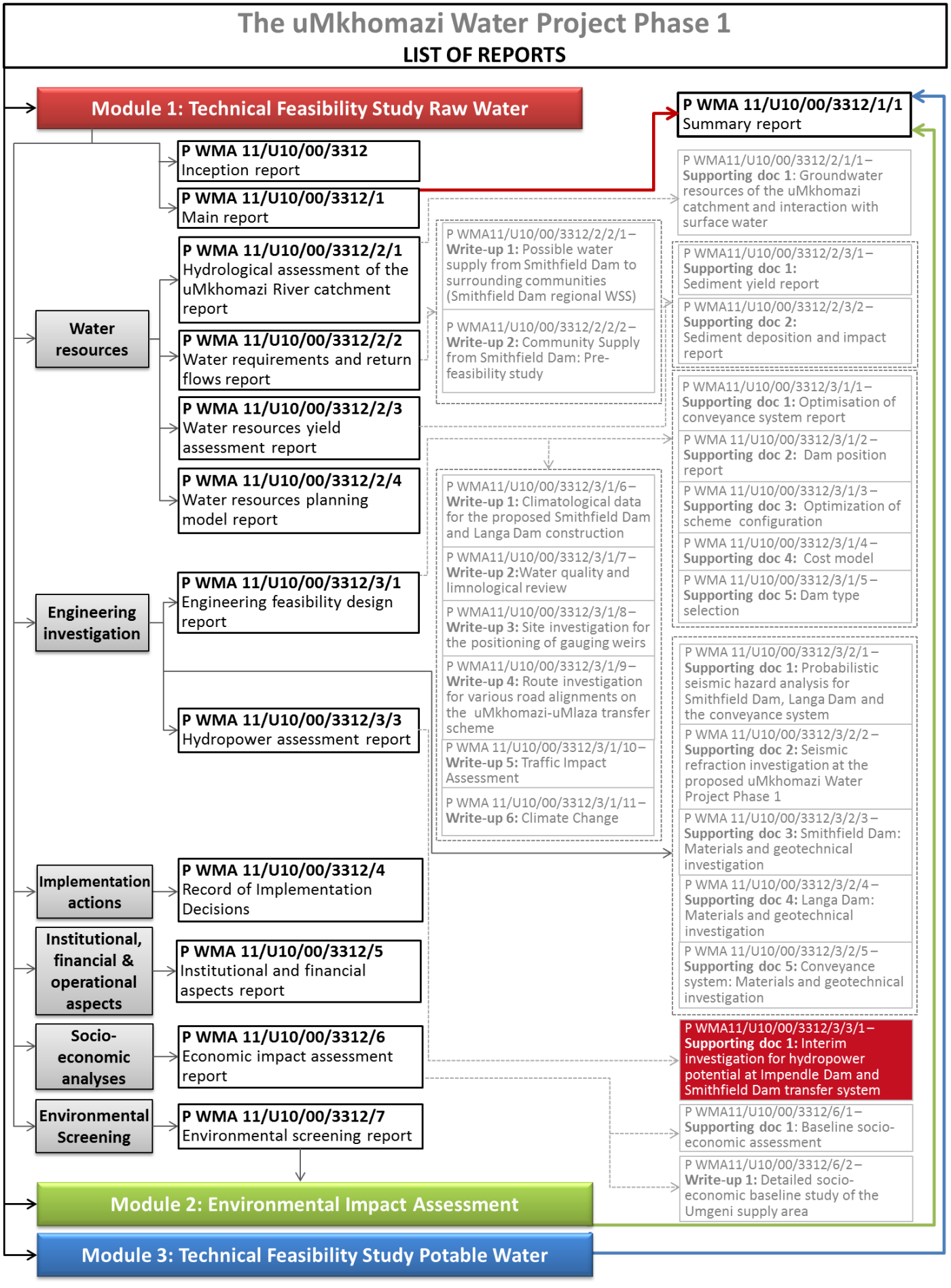
K Bester	***LS Mabuda***
Chief Engineer: Options Analysis (East)	*Chief Director: Integrated Water Resource Planning*

* *BKS (Pty) Ltd was acquired by AECOM Technology Corporation on 1 November 2012*

Prepared by:

AECOM SA (Pty) Ltd
PO Box 3173
Pretoria
0001

In association with:
Africa Geo-Environmental Services **Mogoba Maphuthi and Associates** **Urban-Econ**


The uMkhomazi Water Project Phase 1
LIST OF REPORTS
Module 1: Technical Feasibility Study Raw Water
P WMA 11/U10/00/3312/1/1
Summary report
P WMA 11/U10/00/3312
Inception report
P WMA 11/U10/00/3312/1
Main report
Water resources
P WMA 11/U10/00/3312/2/1
Hydrological assessment of the uMkhomazi River catchment report
P WMA 11/U10/00/3312/2/2
Water requirements and return flows report
P WMA 11/U10/00/3312/2/3
Water resources yield assessment report
P WMA 11/U10/00/3312/2/4
Water resources planning model report
Engineering investigation
P WMA 11/U10/00/3312/3/1
Engineering feasibility design report
P WMA 11/U10/00/3312/3/3
Hydropower assessment report
Implementation actions
P WMA 11/U10/00/3312/4
Record of Implementation Decisions
Institutional, financial & operational aspects
P WMA 11/U10/00/3312/5
Institutional and financial aspects report
Socio-economic analyses
P WMA 11/U10/00/3312/6
Economic impact assessment report
Environmental Screening
P WMA 11/U10/00/3312/7
Environmental screening report
P WMA11/U10/00/3312/2/1/1 – Supporting doc 1: Groundwater resources of the uMkhomazi catchment and interaction with surface water
P WMA11/U10/00/3312/2/2/1 – Write-up 1: Possible water supply from Smithfield Dam to surrounding communities (Smithfield Dam regional WSS)
P WMA11/U10/00/3312/2/2/2 – Write-up 2: Community Supply from Smithfield Dam: Pre-feasibility study
P WMA11/U10/00/3312/2/3/1 – Supporting doc 1: Sediment yield report
P WMA11/U10/00/3312/2/3/2 – Supporting doc 2: Sediment deposition and impact report
P WMA11/U10/00/3312/3/1/1 – Supporting doc 1: Optimisation of conveyance system report
P WMA 11/U10/00/3312/3/1/2 – Supporting doc 2: Dam position report
P WMA 11/U10/00/3312/3/1/3 – Supporting doc 3: Optimization of scheme configuration
P WMA 11/U10/00/3312/3/1/4 – Supporting doc 4: Cost model
P WMA 11/U10/00/3312/3/1/5 – Supporting doc 5: Dam type selection
P WMA11/U10/00/3312/3/1/6 – Write-up 1: Climatological data for the proposed Smithfield Dam and Langa Dam construction
P WMA11/U10/00/3312/3/1/7 – Write-up 2:Water quality and limnological review
P WMA11/U10/00/3312/3/1/8 – Write-up 3: Site investigation for the positioning of gauging weirs
P WMA11/U10/00/3312/3/1/9 – Write-up 4: Route investigation for various road alignments on the uMkhomazi-uMlaza transfer scheme
P WMA 11/U10/00/3312/3/1/10 – Write-up 5: Traffic Impact Assessment
P WMA 11/U10/00/3312/3/1/11 – Write-up 6: Climate Change
P WMA 11/U10/00/3312/3/2/1 – Supporting doc 1: Probabilistic seismic hazard analysis for Smithfield Dam, Langa Dam and the conveyance system
P WMA 11/U10/00/3312/3/2/2 – Supporting doc 2: Seismic refraction investigation at the proposed uMkhomazi Water Project Phase 1
P WMA 11/U10/00/3312/3/2/3 – Supporting doc 3: Smithfield Dam: Materials and geotechnical investigation
P WMA 11/U10/00/3312/3/2/4 – Supporting doc 4: Langa Dam: Materials and geotechnical investigation
P WMA 11/U10/00/3312/3/2/5 – Supporting doc 5: Conveyance system: Materials and geotechnical investigation
P WMA11/U10/00/3312/3/3/1 – Supporting doc 1: Interim investigation for hydropower potential at Impendle Dam and Smithfield Dam transfer system
P WMA11/U10/00/3312/6/1 – Supporting doc 1: Baseline socio-economic assessment
P WMA11/U10/00/3312/6/2 – Write-up 1: Detailed socio-economic baseline study of the Umgeni supply area
Module 2: Environmental Impact Assessment
Module 3: Technical Feasibility Study Potable Water

PREAMBLE

Company name i.e. BKS vs AECOM

*The Department of Water Affairs appointed **BKS (Pty) Ltd** in association with three sub-consultants **Africa Geo-Environmental Services, MM&A and Urban-Econ** with effect from 1 December 2011 to undertake the **uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study Raw Water** study.*

*Subsequently, on 1 November 2012, BKS (Pty) Ltd was acquired by **AECOM Technology Corporation**. As a result of the change in name and ownership of the company during the study period, a decision was made that all the final study reports will be published under the AECOM name.*

However, as this report (P WMA 11/U10/00/3312/3/3/1 – Hydropower assessment report: Supporting document 1: Interim investigation for hydropower potential at Impendle Dam and Smithfield Dam transfer system) has already been published at the time, agreement was reached that the references to BKS will remain within this report as is.

In June 2014, two years after the commencement of the uMkhomazi Water Project Phase 1 Feasibility Study, a new Department of Water and Sanitation was formed by Cabinet, including the formerly known Department of Water Affairs.

In order to maintain consistent reporting, all reports emanating from Module 1 of the study will be published under the Department of Water Affairs name.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

APPENDICES

LIST OF ABBREVIATIONS

BOR	Bottom of River
DWA	Department of Water Affairs
FSL	Full supply level
HPP	Hydropower plant
HWL	Head Water Level
IPP	Independent Power Producer
MAR	Mean annual runoff
MOL	Minimum operating level
NERSA	National Energy Regulator of South Africa
NPV	Net Present Value
REFIT	Renewable Energy Feed In Tariff
ROE	Return on Equity
TOR	Terms of Reference

LIST OF UNITS

Mm^3	Million cubic metres
Mm^3/a	Million cubic metres per annum
m^3/s	Cubic metres per second
Mℓ/d	Mega litres per day
masl	Metres above sea level

1 INTRODUCTION

The Department of Water Affairs (DWA) is currently undertaking a feasibility study of various components of the uMkhomazi Water Supply Scheme (WSS) with the intention of supplementing the supply to the Umgeni Water Supply Area.

The uMkhomazi WSS comprises two dams, namely one at Smithfield and one at Impendle.

It is currently envisaged that Smithfield Dam will be implemented first and will supply water to Umlaas Road via a tunnel and pipe transfer system by 2023. Impendle Dam will be implemented when required.

In light of government's policy of promoting renewable energy DWA instructed its consultants AECOM (previously BKS) to determine the approximate hydropower potential of Impendle Dam and to further estimate the extent to which the sale of hydropower from the dam could offset the costs of constructing the dam.

Additional to this a first order investigation is undertaken for the hydropower potential from Smithfield Dam to the Umlaas road connection. These options will be refined later in the project stage when further information from detailed studies is available.

A number of options utilizing the available water yield or supply from the dams for the generation of continuous power and supply to the nearest transmission network of ESKOM have been considered.

This report contains a rough and ready first order calculation in order to determine whether a more detailed analysis is warranted. Upper and lower bounds for the possible potential for hydropower development are indicated.

2 BACKGROUND

2.1 PROGRAM FOR DEVELOPMENT

The implementation of Smithfield Dam is scheduled as follows:

- Completion of construction in 2021.
- Supply of water to Umgeni River Water Supply Area to be implemented as follows:
  - In year 2023 by 4.07 m^3/s rising linearly to 4.75 m^3/s at an estimated growth of 1.3% per annum, in the year 2035. The available demand is shown in **Figure 2.1**.

Augmentation is required from Impendle Dam in 2035. (This may be postponed if a slightly larger Smithfield Dam is considered). If developed by a private developer, construction of Impendle Dam can be completed by 2018. The water from the dam can be used for the generation of hydropower by releasing water into the river until 2035 when less water will be available for hydropower generation and more for the supply to the Umgeni Water Supply Area. The released water from Impendle Dam will supplement the Smithfield Dam.

The available yield at Impendle will be discussed in the assumptions made for each investigated option.

For this analysis it has been assumed that the development of Impendle Dam for hydropower generation will influence the reservoir levels of Smithfield Dam to be almost at FSL (Yield of and releases into the uMkhomazi River at Impendle Dam ≈ 6 m^3/s and the demand to be supplied from Smithfield Dam ≈ 4 – 5 m^3/s).

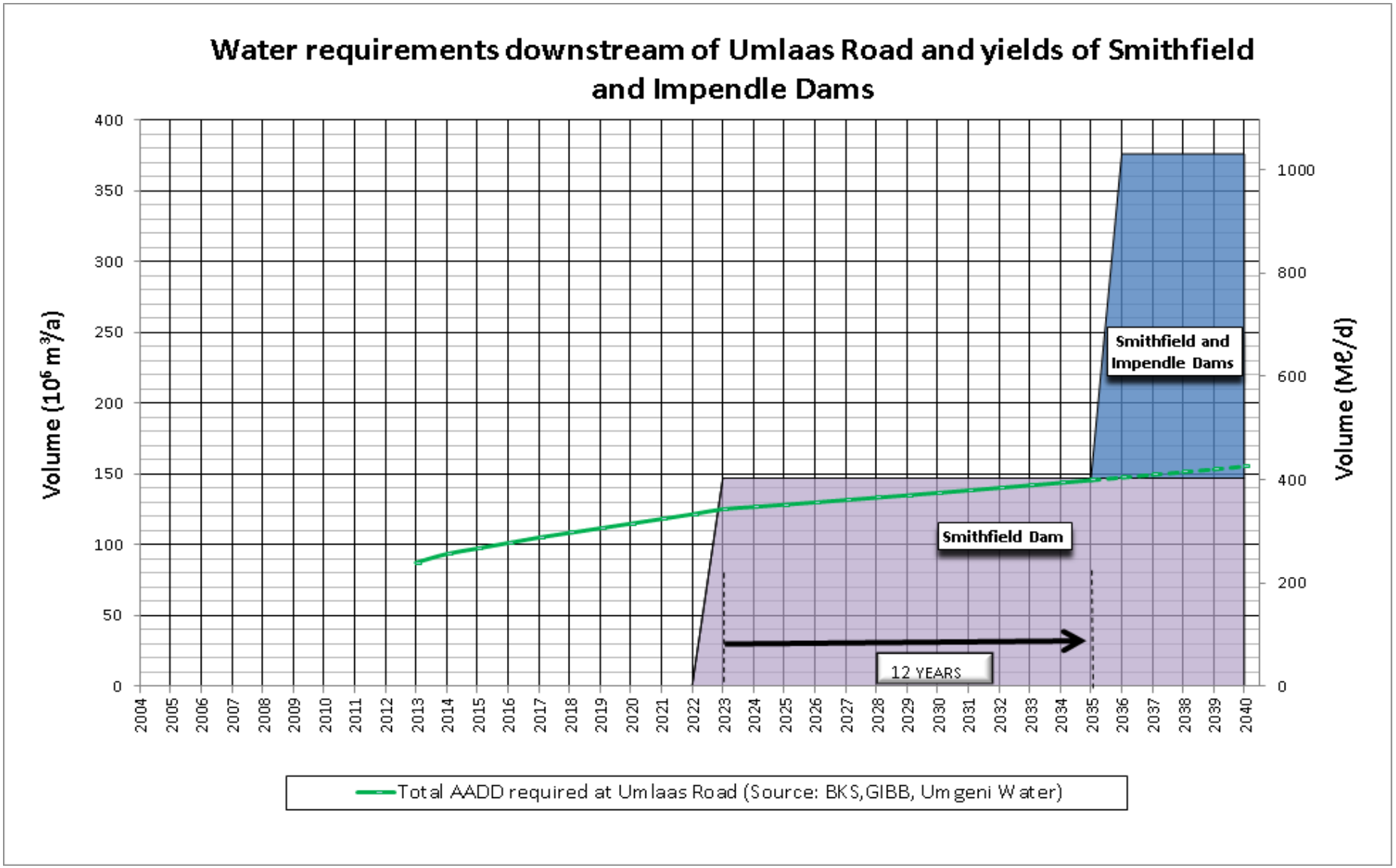


Figure 2.1: Demand curve

3 OPTIONS

3.1 INTRODUCTION

Summaries of the options and layouts are described in this section. Detailed descriptions are included in **Appendix A**.

The high and low hydropower potential is a function of the generating head, water yield, generating efficiency and tariff of sales of electricity. Options for a 30 year economic life (payback period) have been considered.

The high and low hydropower potentials are determined with the 1:20 and the 1:100 year associated yields of the dam and an 80% and 90% system efficiency.

3.2 OPTION 1: IMPENDLE DAM WITH HPP AT DAM

3.2.1 Option 1A: Impendle dam constructed for the generation of electricity

The development of the Impendle Dam is initially independent from the requirement to transfer water to Umlaas Road. The cost for the construction of Impendle Dam is therefore allocated to the capital cost of the hydropower project. When additional water is required it could be sources from Impendle Dam at a cost.

A 1 MAR Impendle Dam and Power Plant are developed to generate hydropower by discharging water in accordance with the yield of the dam. Discharges are more than the reserve requirements and therefore no additional reserve water is released. Power is generated at the dam outlet works.

3.2.2 Option 1B: Impendle Dam constructed for water supply

Impendle Dam is developed for water supply purposes before Smithfield Dam. In this option the cost of Impendle Dam is allocated to water supply and not to power generation. The cost of the weir must be added to the cost of the power plant. A concrete gravity diversion weir (with NOC at 888 masl) at Smithfield Dam position should be constructed to divert the water into the tunnel. This weir could be increase when additional yield is required. Power is generated at the dam outlet works.

The plan layout of Option 1A and Option 1B is shown in **Figure 3.1**.

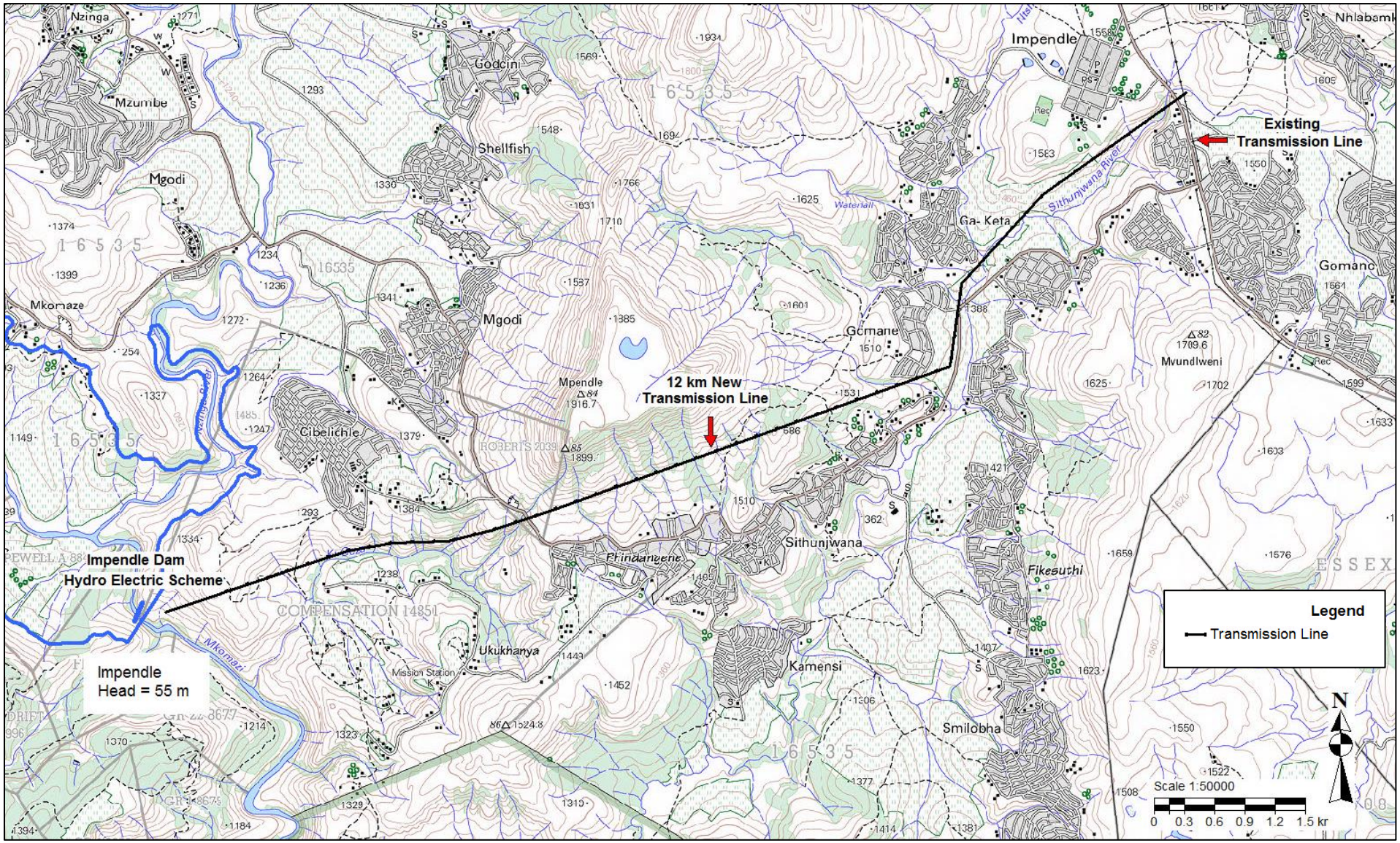


Figure 3.1: Plan layout, Option 1A & 1B – Impendle Dam hydropower

3.3 OPTION 2: IMPENDLE DAM WITH HPP IN TUNNEL SYSTEM

This option's financial assumptions are the same as for Option 1A. A headrace and tailrace tunnel is incorporated to increase the power generation head to ± 150 m.

The tunnel is designed with a near horizontal 2.8 km section, a vertical penstock and a 3.5 m diameter, 1:1000 sloped, 5.1 km discharge tunnel. The plan layout is shown in **Figure 3.2**.

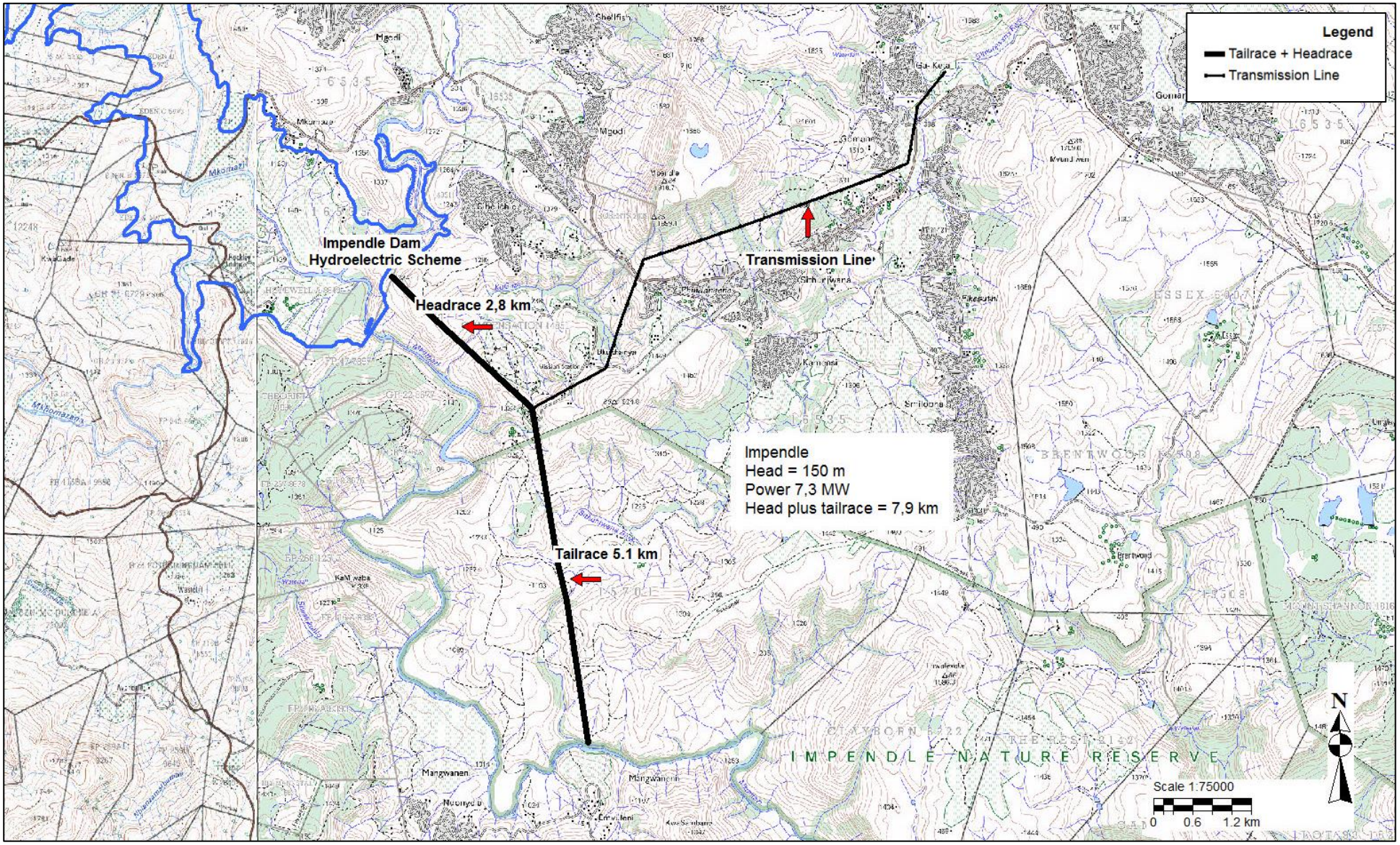


Figure 3.2: Option 2 – Impendle Dam hydropower generation

3.4 OPTION 3: IMPENDLE DAM, SMITHFIELD DAM WITH HPP AT IMPENDLE AND AT THE OUTLET OF THE TRANSFER TUNNEL

This option aims to investigate the potential for hydropower generation along the complete supply system, including the pipe system downstream of Umlaas Road. However, not enough information is available at this stage to determine the hydropower potential at Umlaas Road. This report will be extended, to include Umlaas Road hydropower potential, as information becomes available.

The costs and income of Option 1A and the cost and income of the system at the outlet of the Transfer tunnel were used for this evaluation. Smithfield Dam provides head for transfer of water through the transfer tunnel and generation of hydropower at the outlet of the transfer tunnel.

The transfer tunnel's inlet is in the basin of Smithfield Dam, approximately 1.5 km upstream from Smithfield Dam wall. The EWR can therefore not be utilised for power generation for the transfer tunnel releases and is not used in the calculations.

The transfer tunnel is a pressure tunnel and therefore the power generation should be located downstream of the tunnel.

As Impendle Dam is utilised before the construction of Smithfield Dam and will release water continuously for power generation, it is assumed that Smithfield Dam will, mostly, be at the FSL (exceedance probability curves should be compiled to determine the water level to be used for the generation of hydroelectric power through Smithfield Dam).

The layout of the upstream system is shown in **Figure 3.3** and the layout of the downstream system is shown in **Figure 3.4**.

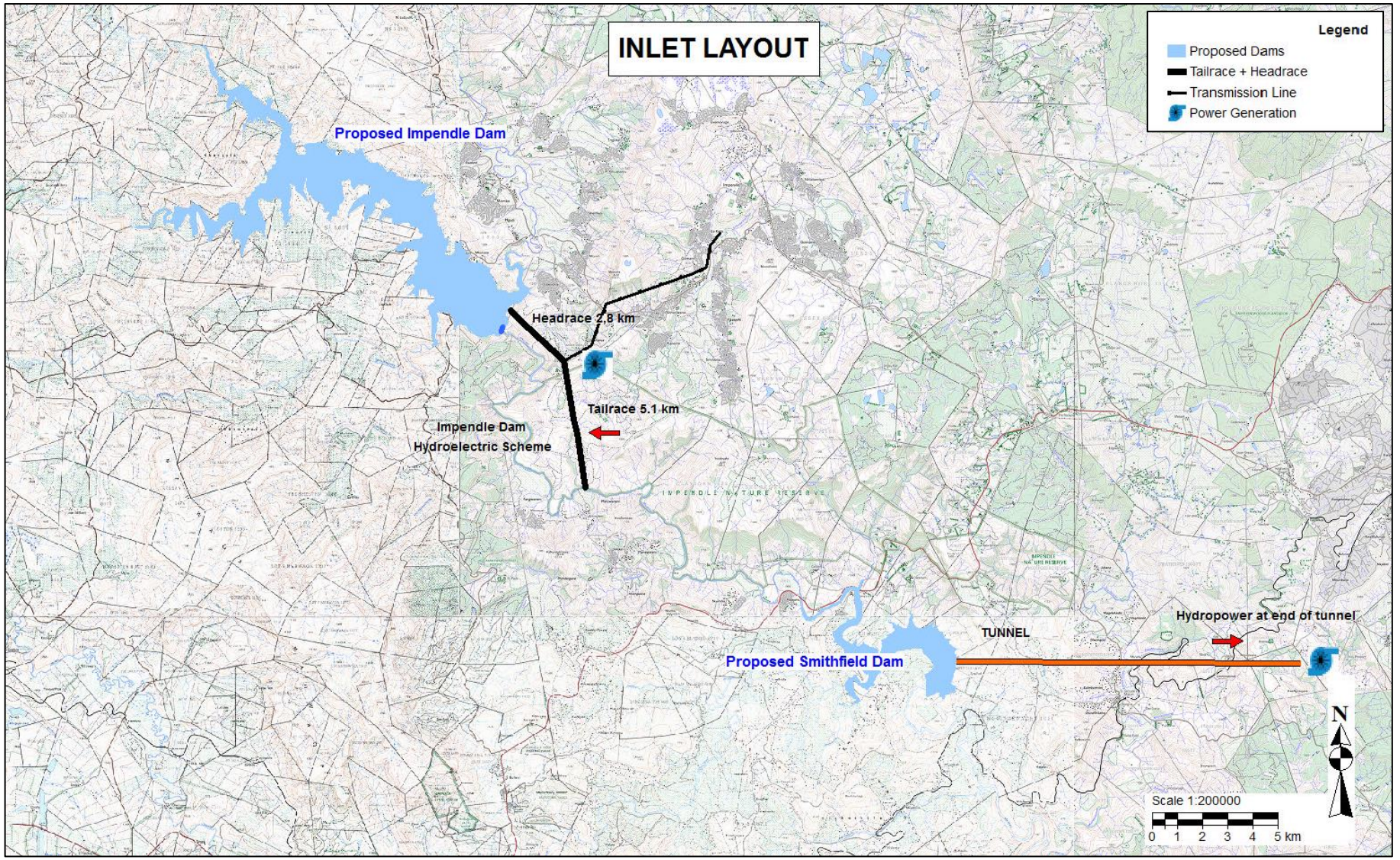


Figure 3.3: Option 3 – Upstream system

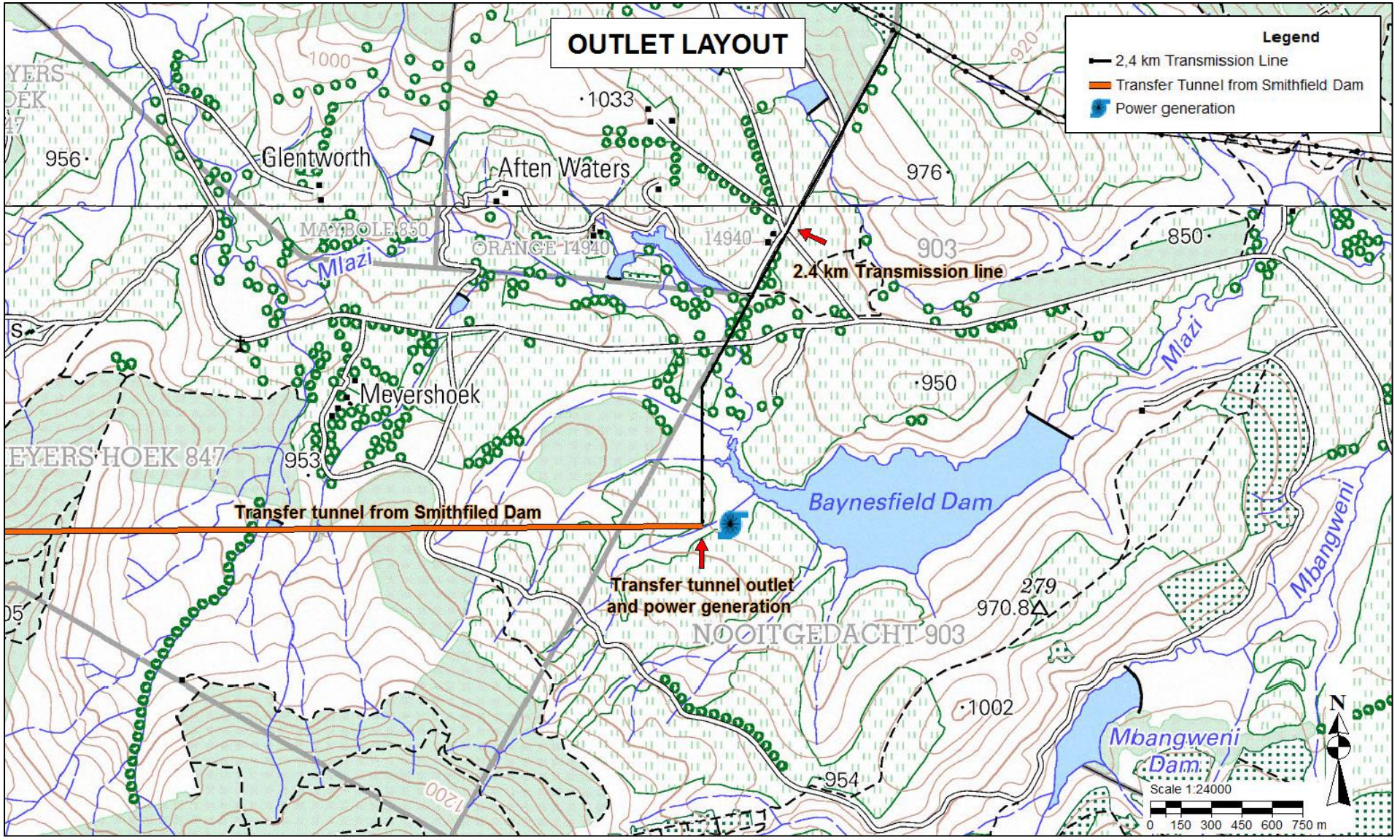


Figure 3.4: Option 3 – Downstream system

4 TECHNICAL ASSUMPTIONS

4.1 SUMMARY TABLES

A summary of the technical assumption are indicated in **Table 4.1**.

Table 4.1: Technical assumptions

Option	1A		1B		2		3 (Baynesfield)	
Potential	High	Low	High	Low	High	Low	High	Low
Available water (million m³/annum)	426	275	378	378	323	275	188	188
Available water (m³/s)	13.5	11.9	11.9	11.9	10.2	8.7	5.96	5.96
Available power generation head (m)	63.7	63.7	63.7	63.7	150	150	27.8	27.8
System efficiency (%)	90	80	90	80	90	80	90	80
Power potential (MW)	7.6	6.7	6.7	5.9	13.5	10.2	1.46	1.3
Annual power to be generated (MWh)	66 475	58 692	58 692	51 684	118 260	89 352	12 815	11 390

4.2 SCHEMATIC OPTION LAYOUT

The schematic sectional layout of the different options is shown in **Figure 4.1** to **Figure 4.4**.

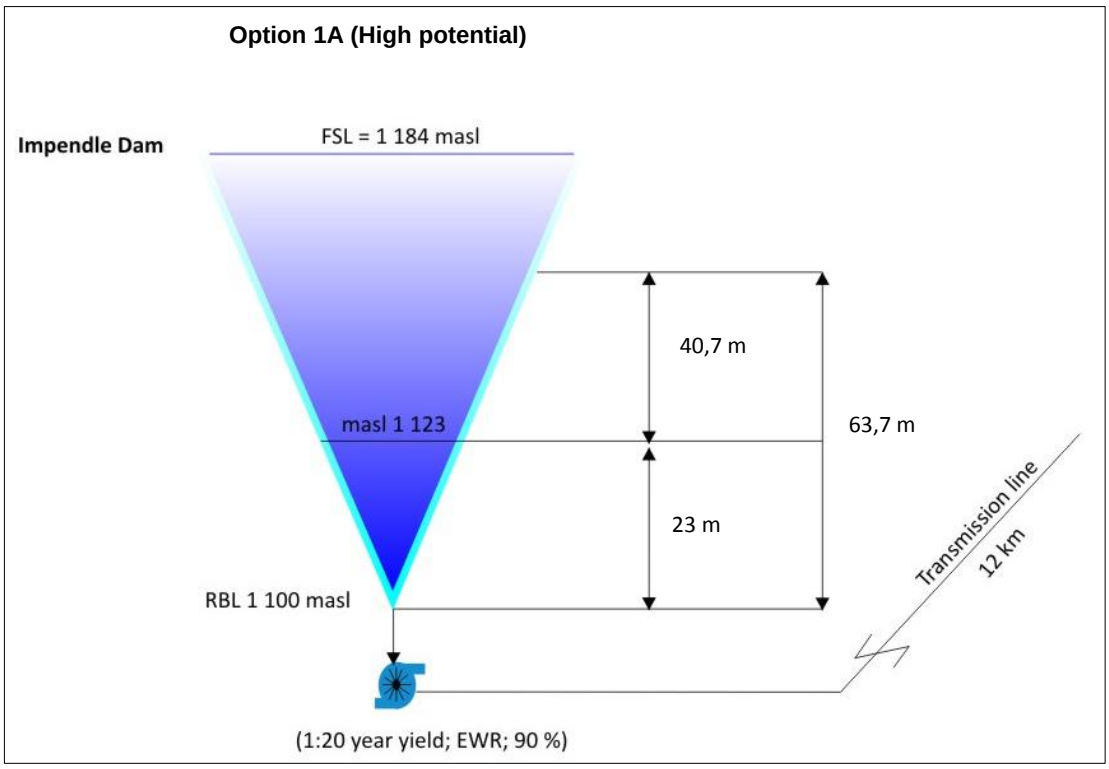


Figure 4.1: Option 1A with high potential layout

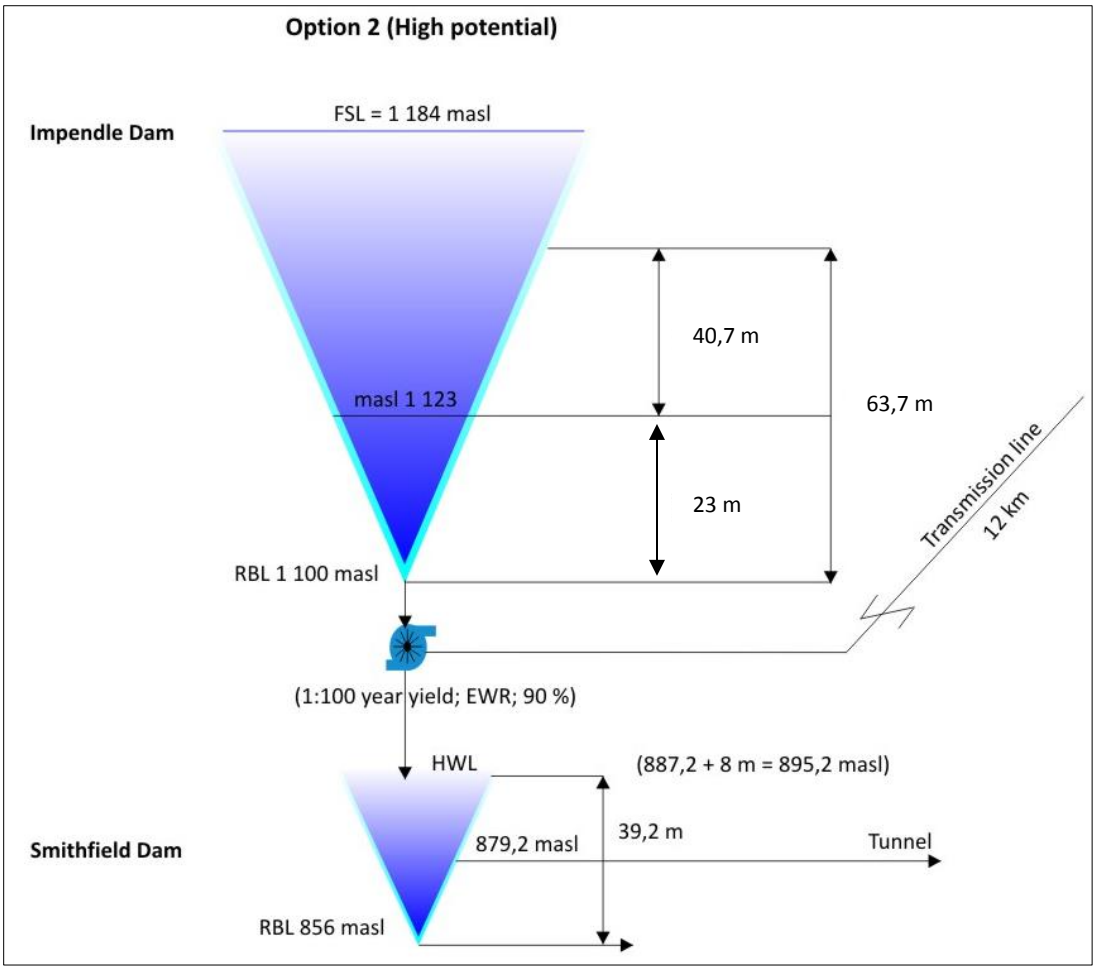


Figure 4.2: Option 1B with high potential layout

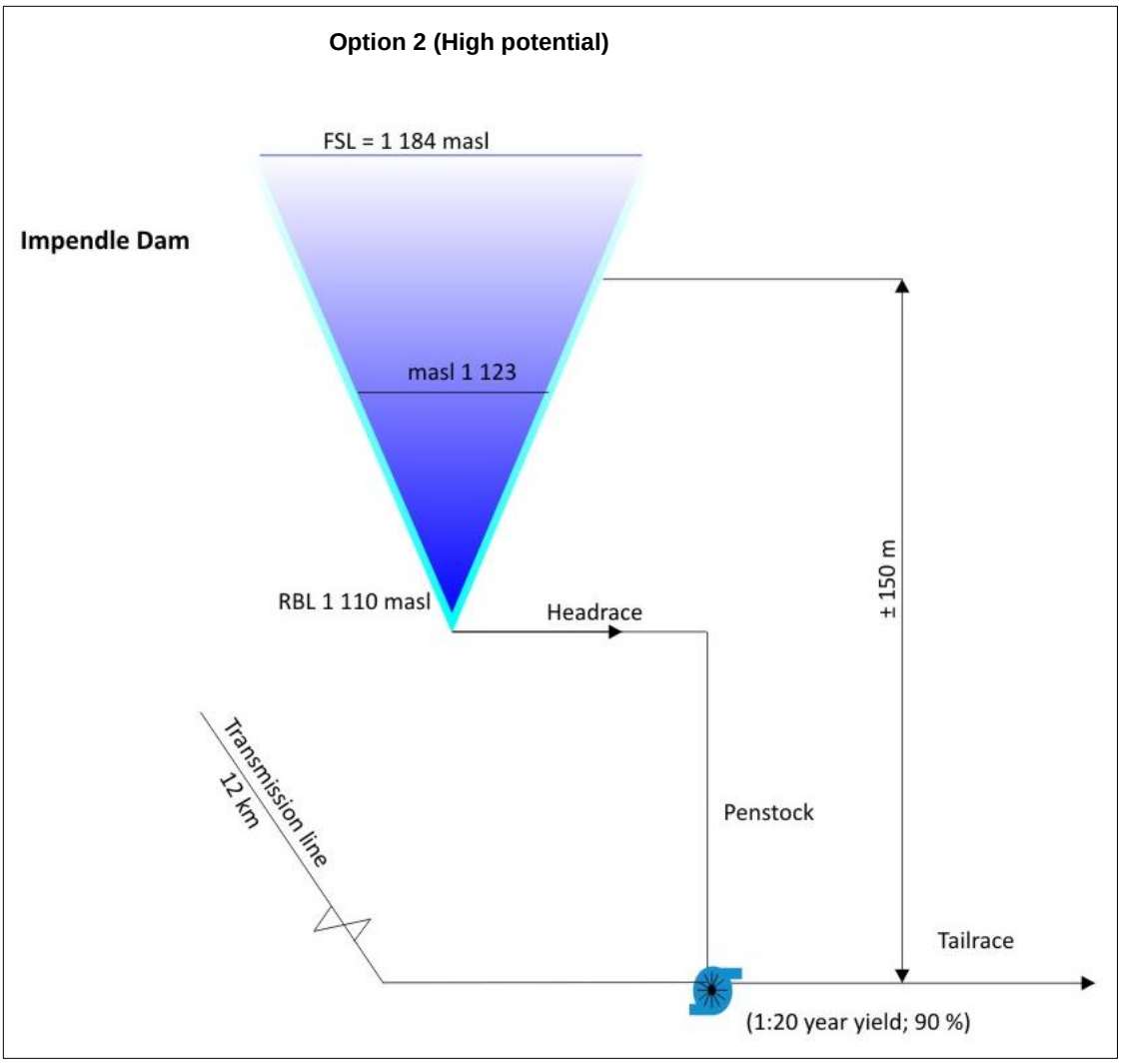


Figure 4.3: Option 2 with high potential layout

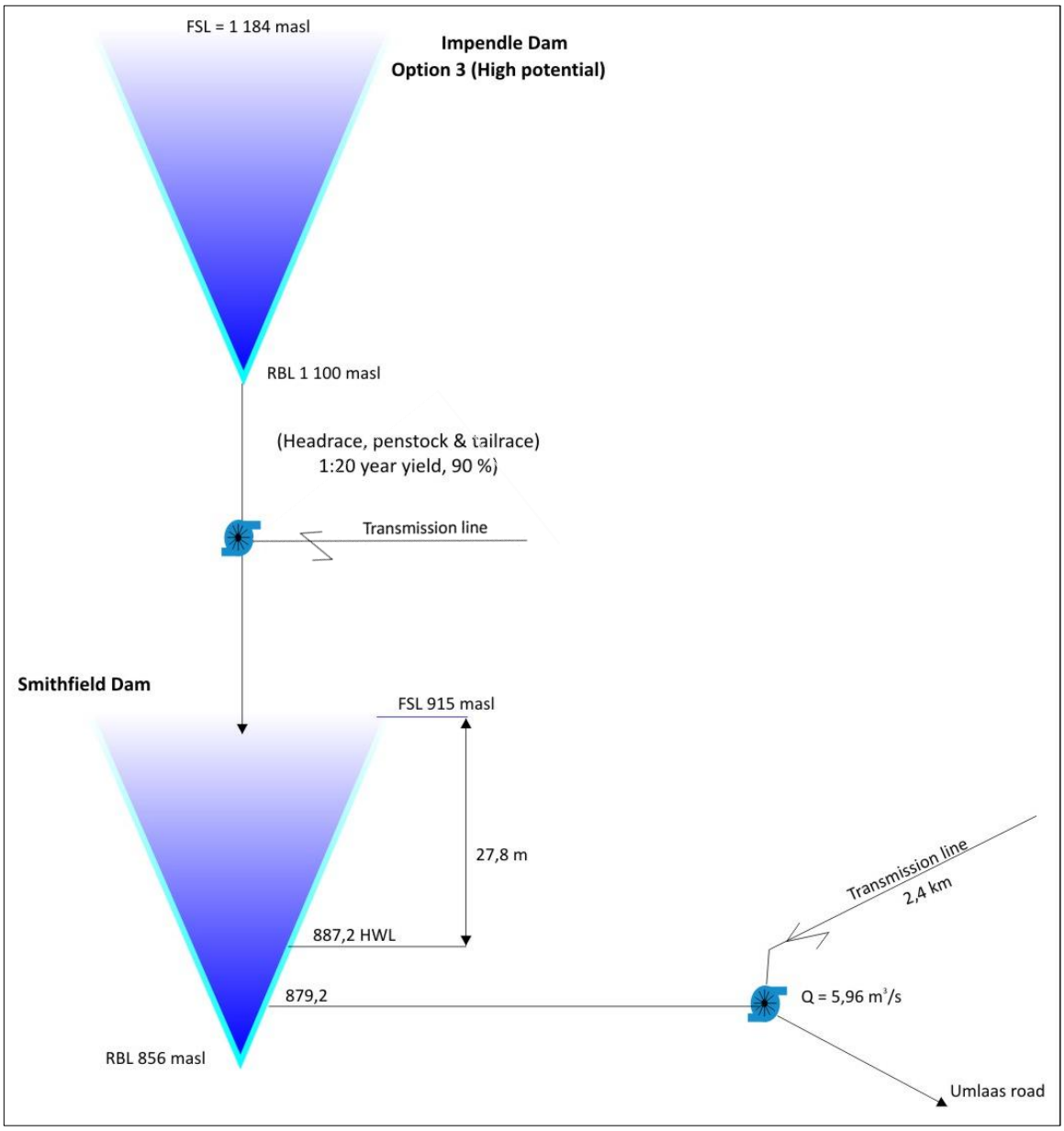


Figure 4.4: Option 3 with high potential layout

5 COSTS OF DEVELOPMENT AND OPERATIONS

The estimated costs for development and operating Impendle Dam and the hydropower station are shown in **Table 5.1**, **Table 5.2** and **Table 5.3**. The estimated cost for the development and operation of the power generation plant for the Smithfield transfer system is shown in **Table 5.4**.

The cost for the hydro-mechanical equipment and the power house is estimated at R 15 million per MW generated. The switchyard cost is estimated as R 29, 775 million. These estimations are obtained from previous projects. It is self-evident that flow and head would also influence the costs and that the power station costs would need to be revisited if it is decided to investigate the hydropower option in more detail.

The Smithfield diversion weir's cost is pro-rated from Impendle Dam cost according to the height (887.2 masl against 39.2 m).

Table 5.1: Option 1A: Cost of construction and operating Impendle Dam and Hydropower Station at dam outlet

Item	Capital 2012 R'000	Operations and Maintenance	Annual cost R'000
Impendle Dam (92 m high)	1 110 833	0.25%	2 777
Power station (8 MW; 14.3 m^3/s)	113 828	4.00%	4 553
Switch yard	29 775	4.00%	1 191
Power line 12 km @ R 0.8 mil per km	9 600	0.50%	48
Engineering and admin	15 320	0.00%	0
Total	1 279 357		8 569

Table 5.2: Option 1B: Cost of constructing and operating Impendle Dam and Hydropower Station at dam outlet

Item	Capital 2012 R'000	Operations and Maintenance	Annual cost R'000
Impendle Dam (cost of dam is allocated to water sales)	0	0.25%	0
Smithfield diversion (39.2 m high)	473 312	0.25%	1 183
Power station (5 MW; 10.2 m^3/s)	100 337	4.00%	4 013
Switch yard	29 775	4.00%	1 191
Power line 12 km @ R 0.8 mil per km	9 600	0.50%	48
Engineering and admin	13 971	0.00%	0
Total	626 995		6 436

Table 5.3: Option 2: Cost of constructing and operating Impendle Dam and Tunnel

Item	Capital 2012 R'000	Maintenance	Annual cost R'000
Impendle Dam	1 110 833	0.25%	2 777
Tunnel	550 000	0.25%	1 375
Power station (13.8 MW; 10.2 m^3/s)	202 626	4.00%	8 105
Switch yard	29 775	4.00%	1 191
Power line 12 km @ R 0.8 mil per km	9 600	0.50%	48
Engineering and admin	24 200	0.00%	0
Total	1 927 034		13 496

Table 5.4: Option 3: Baynesfield - Power Generation Plant

Item	Capital 2012 R'000	Maintenance	Annual cost R'000
Smithfield Dam and Tunnel	0	0.25%	0
Power station (0.9 MW; 5.9 m^3/s)	21 943	4.00%	878
Switch yard	29 775	4.00%	1 191
Power line 2.4 km @ R 0.8 mil per km		0.50%	10
Engineering and admin	5 364	0.00%	0
Total	59 002		2 078

6 FINANCIAL ASSUMPTIONS

The income from the sale of electricity is a crucial factor in the determination of hydropower potential. The Renewable Energy Feed-In Tariffs (REFIT) as proposed by the National Energy Regulator of South Africa (NERSA) is used as a low potential income and the more real value as recommended by the Department of Energy is used in the high potential scenario. The results of the income based on these assumptions are indicated in **Table 6.2**.

6.1 NERSA

NERSA has made a number of financial assumptions in determining an equitable REFIT tariff based on the notion that the IPP would be a private sector company. NERSA's assumptions are shown in **Table 6.1** below:

Table 6.1: NERSA assumptions

Item	Amount
Debt	70.00%
Equity	30.00%
Nominal cost of debt	9.93%
Inflation	6.00%
Real cost of debt before tax	3.71%
Tax rate	28.00%
Real return on Equity ROE after tax	17.00%
Weighted average cost of capital (WACC) after tax	9.80%
Small hydro REFIT tariff (Amount used for low potential)	R 0.675

It can be calculated from the above 70:30 debt equity weightings and interest and rate of return requirements that a **real** rate of return of **7.70%** would be required by a private IPP (if tax is ignored on the assumption that interest charges and depreciation would cancel profits and that depreciation charges would not be used to refurbish the works).

However, if the scheme were to be fully funded with debt finance by a public entity that was not seeking profit, then the required **real** rate of return would be **3.71%**.

6.2 DEPARTMENT OF ENERGY

Some discussion and investigations indicates that the Department of Energy could be willing to pay up to R1.20 per kWh of energy delivered. Some municipalities are even willing to pay additional to this amount. An amount of R1.20 was used in the financial calculations for a high potential.

Table 6.2: Income from hydropower

Option	1		2		3		4 (Smithfield)	
Potential	High	Low	High	Low	High	Low	High	Low
Income per kWh (R/kWh)	1.2	0.675	1.2	0.675	1.2	0.675	1.2	0.675
Annual Income (R million)	79.8	39.9	70.3	35.1	142	71	15.4	7.7
Max water for sale in 2050 (million m^3/annum)	32	32	0	0	32	32	0	0
Assumed cost of water (R/m^3)	2	1.5	0	0	2	1.5	0	0

7 NET PRESENT VALUE

The information contained in this report was used in the calculation of the Net Present Value of the four different options. Only the high potential NPV was calculated for the purpose of this report. A summary of the results are shown in **Table 7.1**.

Table 7.1: NPV results

Option	1A	1B	2	3 (Smithfield)	2&3
Potential	High	High	High	High	High
At a 7.7% rate	-396 465	22 218	-447 595	57 135	-390 460
At a 3.71% rate	91 224	397 977	370 331	144 700	515 030

8 CONCLUSIONS

The following conclusions can be made:

- More accurate results in terms of available yields and power generation head will be possible after the completion of this feasibility stage.
- The generation of electricity from hydropower seems feasible if the Dam utilised for hydropower is constructed for the supply of water and the cost not added to the capital cost for hydropower generation (Options 1B and 3).
- Determination of the hydropower potential for Option 3, forms part of the current, Module 1, Technical Feasibility study and the viability of this option will be investigated under this project when all required information have been obtained.

9 RECOMMENDATIONS

The following recommendations are made:

- The amount received from the sale of electricity should be researched and a more detailed sensitivity analysis should be completed;
- The capital cost of projects is crucial in the viability of any hydropower project and Options 1A, 1B and 2 should be investigated up to pre-feasibility stage in order to determine the cost in more detail (specially Hydro-mechanical cost). (Option 3 will be investigated through the current project);
- The generation option to Umlaas Road should be investigated when more information is available regarding the system network to Umlaas Road connection;
- The necessity for electricity and the strategic importance for renewable energy could outweigh any negative NPVs. ESKOM should be approached and the generation potential highlighted;

10 REFERENCES

Ninham Shand Consulting Engineers (1999), *Mkomazi-Mgeni Transfer Scheme Pre-feasibility Study, Supporting Report No. 4, Hydrology & Water Resources*, Department of Water Affairs in association with Umgeni Water Corporate Services Division.

Ninham Shand Consulting Engineers (1999), *Mkomazi-Mgeni Transfer Scheme Pre-feasibility Study, Supporting Report No. 6, Engineering Design & Costing, Volume 1*, Department of Water Affairs in association with Umgeni Water Corporate Services Division.

BKS (Pty) Ltd (July 2012), *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water. Supporting Document, Task 5.1 Optimisation of Conveyance System Report.*

Appendix A

Option description and assumptions

1. IMPENDLE DAM - OPTION 1A

1.1 SYSTEM DESCRIPTION

Impendle Dam (1 MAR Dam) is constructed for hydropower purposes by private developers and power is generated at the dam outlet works, by 2018. The Smithfield Dam will be constructed as planned and independent from the Impendle Dam. In this option the cost of Impendle Dam is allocated to hydropower generation.

1.2 AVAILABLE POWER GENERATION YIELD

1.2.1 High Potential

After construction at 2018 Impendle will be able to release the full yield for hydropower generation. The available power generation yield of Impendle Dam will be the 1:20 year firm yield plus the required EWR (323 + 103 = 426 million m³/a or 13,5 m³/s) [1].

1.2.2 Low Potential

With a higher level of assurance required, the 1:100 year firm yield of Impendle Dam is in the order of 275 million m^3/annum. The EWR can be added to this to provide a yield of 378 million m³/annum or 11.9 m^3/s.

1.3 AVAILABLE POWER GENERATION HEAD

A 1 MAR Impendle Dam have a FSL at 1 184 masl and a MOL of 1 123 masl [2]. Based on an effective average head of 67% of the head between MOL and FSL, the head would be 40,7 m. The RBL at 1 100 masl is 23 m lower than MOL. Therefore a head of 63,7 m for power generation can be provided.

1.4 POWER GENERATION AND INCOME

The power transmission layout is shown in **Figure 4.1**.

1.4.1 High Potential

With the previous assumptions 7,6 MW of power can be generated or 66,5 MWh/annum at a 90% efficiency.

The Department of Energy Tarrifs up to R1,20 have been used for sales. The sales based on this value would be approximately R 79,8 million per annum.

1.4.2 Low Potential

For the low potential option 6.7 MW or 58,6 MWh/annum could be generated at 80% efficiency.

At energy sales of Nersa's current REFIT tariff of R0.675 /kWh the income would be approximately R39,6 million per annum.

1.5 WATER INCOME

After 2035 the system will require that water from Impendle Dam be utilised for water supply. As Impendle was constructed by private enterprise, Impendle should receive income for the supply of water to the system. The demand from the system at 2035 will be 4,75 m³/s (149,8 million m³/a). At 2052 the demand from the system will be 5,92 m³/s (186,6 million m³/a). Impendle Dam will therefore have to supply and could sell 36,8 million m³/a during 2052. Provision for the sale of water is made in the NPV calculations at a growth rate of 1,3% per annum and at a R2/m³ high potential income and a R1,5 /m³ low potential income.

2. IMPENDLE DAM - OPTION 1B

2.1 SYSTEM DESCRIPTION

Impendle Dam is constructed for water supply purposes before Smithfield Dam. A concrete gravity diversion weir (with NOC at 888 masl) at Smithfield Dam position should be constructed to divert the water into the tunnel. This weir could be increase when additional yield is required. Power is generated at the dam outlet works.

In this option the cost of Impendle Dam is allocated to water supply and not to power generation. The cost of the weir must be added to the cost of the power plant.

2.2 Available Power Generation Yield

As Impendle Dam would be utilised as a water supply scheme a higher assurance of delivery will be required. The 1:100 year firm yield is therefore considered for releases and hydropower generation plus the EWR (275+103 = 378 million m³/ annum or 11,9 m³/s) [1].

2.3 Available Power Generation Head

A 1 MAR Impendle Dam have a FSL at 1 184 masl and a MOL of 1 123 masl [2]. The available water level for abstraction will be 61 m. If it is assumed that available dam level will be at 67% of this level, a 40,7 m will be available. The RBL is at 1 100 masl and therefore provide an additional head of 23 and therefore provide a head of 63,7 m for power generation.

2.4 Power generation and income

The power transmission layout is shown in **Figure 4.2**.

2.4.1 High Potential

With the previous assumptions 6,7 MW of power can be generated or 58,6 MWh/annum at a 90% efficiency.

The Department of Energy Tarrifs up to R1,20 have been used for sales. The sales based on this value would be approximately R 70,3 million per annum.

2.4.2 Low Potential

For the low potential option 5,9 MW or 51,7 MWh/annum could be generated with a 80% efficiency.

Energy sales at Nersa's current REFIT tariff of R0.675 /kWh would be approximately R34,9 million per annum.

2.5 Water Income

No income from the sale of water is provided for as Impendle is constructed for the supply of water.

3 IMPENDLE DAM - OPTION 2

3.1 SYSTEM DESCRIPTION

Impendle Dam (1 MAR Dam) is constructed for hydropower purposes by private developers and power is generated with a pressure tunnel to downstream. The tunnel is calculated with a near horizontal 2,8 km outlet from the dam, a vertical penstock and a 3,5 m diameter, 1:1000 sloped, 5,1 km discharge tunnel. The schematic layout is shown in **Figure 3.2**.

3.2 AVAILABLE POWER GENERATION YIELD

3.2.1 High Potential

After construction at 2018 Impendle will be able to release the full yield for hydropower generation. The available power generation yield of Impendle dam will therefore be the 1:20 year firm yield. However, the EWR cannot be utilised as it should bypass the tunnel. (323 million m³/a or 10,2 m³/s)[1].

3.2.2 Low Potential

With a higher level of assurance required, the 1:100 year firm yield of Impendle Dam is in the order of 275 million m^3/annum (8,7 m³/s) with the EWR not available.

3.3 AVAILABLE POWER GENERATION HEAD

A 1 MAR Impendle Dam have a FSL at 1 184 masl and a MOL of 1 123 masl [2]. The available water level for abstraction will be 61 m. If it is assumed that available dam level will be at 67% of this level, a 40,7 m will be available. The RBL is at 1 100 masl and therefore provide an additional head of 23 and therefore provide a head of 63,7 m for power generation from the dam.

The water is released into the power generation system. The system will be able to transfer the 11,1 m³/s with an inlet at 1 100 masl, an outlet at 1 000 masl, an available head of ± 150 m for power generation is assumed.

The power transmission and system plan layout is shown in **Figure 4.3**.

3.4 POWER GENERATION AND INCOME

3.4.1 High Potential

With the previous assumptions 13,5 MW of power can be generated or 118,3 MWh/annum at a 90% efficiency.

The Department of Energy Tarrifs up to R1,20 have been used for sales. The sales based on this value would be approximately R 142 million per annum.

3.4.2 Low Potential

For the low potential option 10,2 MW or 98,7 MWh/annum could be generated at a 80% efficiency.

Energy sales at Nersa's current REFIT tariff of R0.675 /kWh would be approximately R60,5 million per annum.

3.5 WATER INCOME

With the same reasoning as for Option 2, income from water sales will also be generated for Option 3 implementation.

4. IMPENDLE DAM - OPTION 3

The need for peak time electricity will negatively impact on the NPV calculations as a larger power station would be required with the same amount of income generated as for Option 1 and Option 2. The kWh sold per year will be the same with double the power generation but for only a 12 hour period per day. This option was not investigated further.

5. IMPENDLE DAM – OPTION 1B, SMITHFIELD DAM AND TRANSFER TUNNEL

5.1 INTRODUCTION

Impendle Dam Option 1B was determined to be the most viable (previous section). However, Option 1B will have no additional head available as only a low dam will be constructed at Smitfield to obtain sufficient head for the losses through the transfer tunnel. Option 2 (and Option 1A) will provide for a large dam at Smithfield and therefore this option is used with the transfer tunnel in order to determine the hydroelectric potential to the end of the transfer tunnel at Baynesfield Dam.

5.2 SMITHFIELD DAM POTENTIAL

The transfer tunnel inlet is in the basin of Smithfield Dam, approximately 1,5 km upstream from the dam wall. The EWR can therefore not be utilised for power generation for the transfer tunnel releases and is not used in the calculations.

The transfer tunnel is proposed to be a pressure tunnel and therefore the power generation should be located downstream of the tunnel.

As Impendle Dam is utilised before the construction of Smithfield Dam and will release water continuously for power generation, it is assumed that Smithfield Dam will, mostly, be at the FSL (exceedance probability curves should be compiled to

determine the water level to be used for the generation of hydroelectric power through Smithfield Dam).

The head required to deliver the required water through the transfer tunnel is at 887,2 masl (HWL). The difference between the FSL (915 masl) and this HWL is used in the calculation of the hydro potential head.

The transfer tunnel is designed to transfer the demand at a peak factor of 1,5. However, for the generation of hydropower the average requirement of 5,96 m^3/s is used.

Appendix B

Calculations

TECHNICAL INFORMATION

NERSA Financial parameters		DEA parameter
Debt	70.00%	
Equity	30.00%	
Nominal cost of debt	9.93%	
Inflation	6.00%	
Real cost of debt before tax	3.71%	
Tax rate	28.00%	
Real return on Equity ROE after t	17.00%	
Weighted average cost of capit	**9.80%**	
Real rate required (ignoring tax	**7.70%**	
Small hydro REFIT 2012 (kWh)	R 0.675	R 1.20

Option 1: Impendle Dam outlet (High potential)		
FSL	1184	masl
MOL	1123	masl
River bed level	1100	masl
Dam height	84	m
Average hydropower head	63.7	m
Yield Phase 1	13.5	m^3/s
Hydraulic and power efficiency	90%	
Power generated	7.59	MW
Per annum	66 475	MWh
Energy sales	**79 771**	R'000
Water sales	2	R/m^3

Option 2: Impendle Dam outlet (High potential)		
FSL	1184	masl
MOL	1123	masl
River bed level	1100	masl
Dam height	84	m
Average hydropower head	63.7	m
Yield Phase 1	11.9	m^3/s
Hydraulic and power efficiency	90%	
Power generated	6.69	MW
Per annum	58 597	MWh
Energy sales	**70 316**	R'000

Option 3: Impendle Dam with tunnel		
Average hydropower head	150	m
Yield Impendle	349	mill^3 m/a
Hydropower flow	10.20	m^3/s
Hydraulic and power efficiency	90%	
Power generated	13.51	MW
Per annum	118 333	MWh
Energy sales	142 000	**R'000**

INPUT COSTS

OPTION 1A: INPUT COSTS IMPENDLE DAM CONSTRUCTED FOR HYDRO POWER				
Item	**Capital 2012**	**Maintenance**	**Annual cost**	Springrove 2009 estimates
	7.6 MW, 13.5 m^3/s			5.48 MW, 3.12 m^3/s
Impendle Dam	1 110 833	0.25%	2 777	
Power station	113 828	4.00%	4 553	110 880
Switch yard	29 775	4.00%	1 191	25 000
Power line 12Km @ R0,8m per km	9 600.0	0.50%	48	
Engineering and admin	15 320	0.00%	0	
Total	**1 279 357**		**8 569**	

OPTION 1B: INPUT COSTS IMPENDLE DAM CONSTRUCTED FOR WATER			
Item	**Capital 2012**	**Maintenance**	**Annual cost**
	6.7 MW, 11.9 m^3/s		
Impendle Dam	0	0.25%	0
Smithfield Diversion weir	473 312	0.25%	1 183
Power station	100 337	4.00%	4 013
Switch yard	29 775	4.00%	1 191
Power line 12Km @ R0,8m per km	9 600.0	0.50%	48
Engineering and admin	13 971	0.00%	0
Total	**626 995**		**6 436**

OPTION 2: INPUT COSTS IMPENDLE DAM AND TUNNEL			
Item	**Capital 2012**	**Maintenance**	**Annual cost**
	13.5 MW, 10.2 m^3/s		
Impendle Dam	1 110 833	0.25%	2 777
Tunnel	550 000	0.25%	1 375
Power station	202 626	4.00%	8 105
Switch yard	29 775	4.00%	1 191
Power line 12Km @ R0,8m per km	9 600.0	0.50%	48
Engineering and admin	24 200	0.00%	0
Total	**1 927 034**		**13 496**

OPTION 3: INPUT COSTS SMITHFIELD DAM CONSTRUCTED FOR WATER SUPPLY				
Item	**Capital 2012**	**Maintenance**	**Annual cost**	**Springrove 2009 estimates**
	1.4 MW, 5.96 m^3/s			5.48 MW, 3.12 m^3/s
Smithfield Dam	0	0.25%	0	
Power station	21 943	4.00%	878	110 880
Switch yard	29 775	4.00%	1 191	25 000
Power line 2,4km @ R0,8m per km	1 920	0.50%	10	
Engineering and admin	5 364	0.00%	0	
Total	**59 002**		**2 078**	

RESULTS

OPTION 1A

Results	Real rate of 7.7%	Real rate of 3.71%
PV Costs	-1 139 553	-1 299 198
PV Electricity sales	680 413	1 212 370
PV Water sales	62 675	178 052
NPV	**-396 465**	**91 224**

OPTION 1B

Results	Real rate of 7.7%	Real rate of 3.71%
PV Costs	-577 553	-670 705
PV Electricity sales	599 771	1 068 682
NPV	**22 218**	**397 977**

OPTON 2

Results	Real rate of 7.7%	Real rate of 3.71%
PV Costs	-1 721 476	-1 965 868
PV Electricity sales	1 211 206	2 158 146
PV Water sales	62 675	178 052
NPV	**-447 595**	**370 331**

OPTION 3

Results	Real rate of 7.7%	Real rate of 3.71%
PV Costs	-65 799	-84 949
PV Electricity sales	122 934	229 648
NPV	**57 135**	**144 700**

Impendle (Opt 2) and Option 4	-390 460	515 030